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THERMAL HYDRAULIC ANALYSIS OF A GAS TEST LOOP SYSTEM

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INTRODUCTION

A Gas Test Loop (GTL) system is currently being designed to provide a high intensity fast-flux irradiation environment for testing fuels and materials for advanced concept nuclear reactors. Potential users of the GTL include the Generation IV Reactor Program, the Advanced Fuel Cycle Initiative and Space Nuclear Programs. This paper presents the results of the thermal hydraulic analysis of a GTL design.

DESIGN REQUIREMENTS AND COMPONENT DESCRIPTION

To assess the performance of candidate reactor fuels, these fuels must be irradiated under actual fast reactor flux conditions and operating environments, preferably in an existing irradiation facility [1]. The GTL system is being designed for operation in the northwest test lobe of the Advanced Test Reactor (ATR) at the Idaho National Laboratory. The Technical and Functional Requirements (T&FRs) for the GTL stipulate a minimum neutron flux intensity (10^{15} n/cm^2·s) and fast to thermal neutron ratio (>15) for the test environment [2]. The incorporation of booster fuel within the test lobe is necessary to achieve these neutron flux requirements. Additionally, the use of a neutron filter is necessary to create a fast neutron environment in a thermal reactor, such as ATR.

Figure 1 illustrates the configuration analyzed here. The test train configuration consists of three experiment tubes, each surrounded by a neutron filter. The annular regions between the experiment tubes and the neutron filters and the region between the neutron filters and the pressure tube are cooled by flowing helium gas. Hollow spacer assemblies serve to reduce the flow area available for the helium coolant, thereby increasing its velocity and decreasing the required volume of helium to pump across the test loop.

The entire test train is enclosed within a structural mid-section, consisting of a pressure tube and an envelope tube concentrically arranged and separated by a small helium gap for leak detection monitoring. The envelope tube is surrounded by three concentric rings of U_3Si_2 booster fuel clad with 6061 aluminum. The booster fuel assembly (BFA) is cooled with Advanced Test Reactor (ATR) primary coolant at a flow rate of approximately 600 gpm (22.71 l/m). To be consistent with ATR Safety Analysis, a 1.5 mil (38.1 μm) oxide layer on the surface of the fuel cladding is modeled. The entire arrangement of the test train and booster fuel assembly is enclosed within a flux trap baffle. Heat loads for the GTL components were provided from neutronics calculations.

RESULTS

Thermal hydraulic analysis was performed using RELAP5-3D©/ATHENA to determine the steady-state operating temperatures of the Gas Test Loop (GTL) components with an experiment heat load of 225 kW. Figure 2 shows the maximum predicted steady-state temperatures. The maximum temperature of the neutron filter (496 K [433 ºF]) occurs at the inner diameter of the filter ring, and is lower than the temperature at which hydrogen embrittlement of the hafnium might become a problem. The helium gas cooling system is effective in removing heat from the experiment loop and pressure tube at a helium flow rate of 5189 lbm/hr. The pumping power for a 50 psid pressure drop across the GTL is estimated at 141 kW (189 hp). The maximum temperature of the BFA occurs at the inner plate, with a fuel centerline temperature of 520 K (476 ºF) and a cladding surface temperature of 424 K (304 ºF), which are acceptable. The highest coolant outlet temperature of 385 K (233 ºF) occurs in the coolant channel between fuel plates 1 and 2. At this location, the flow instability margin is 2.7.

These preliminary calculations show that the proposed configuration is a viable design. The design will continue to be refined as additional information becomes available.

REFERENCES

1. "Justification of Mission Need for the Gas Test Loop," Idaho National Laboratory, INEEL/EXT-04-02018, June 2004.
2. Longhurst, G.R., and Khericha, S.T., "Gas Test Loop Technical and Functional Requirements," Draft, Rev. A, Idaho National Laboratory, INEEL/EXT-04-02273, July 2005.

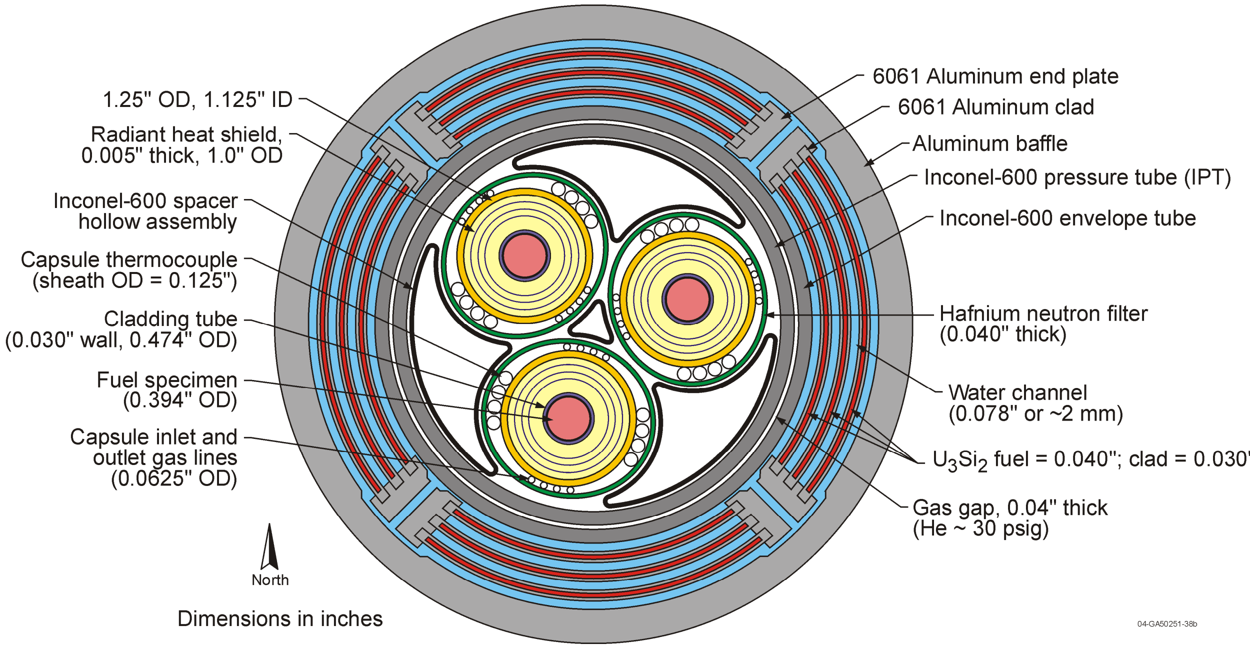

Fig. 1. Gas Test Loop configuration RC5.

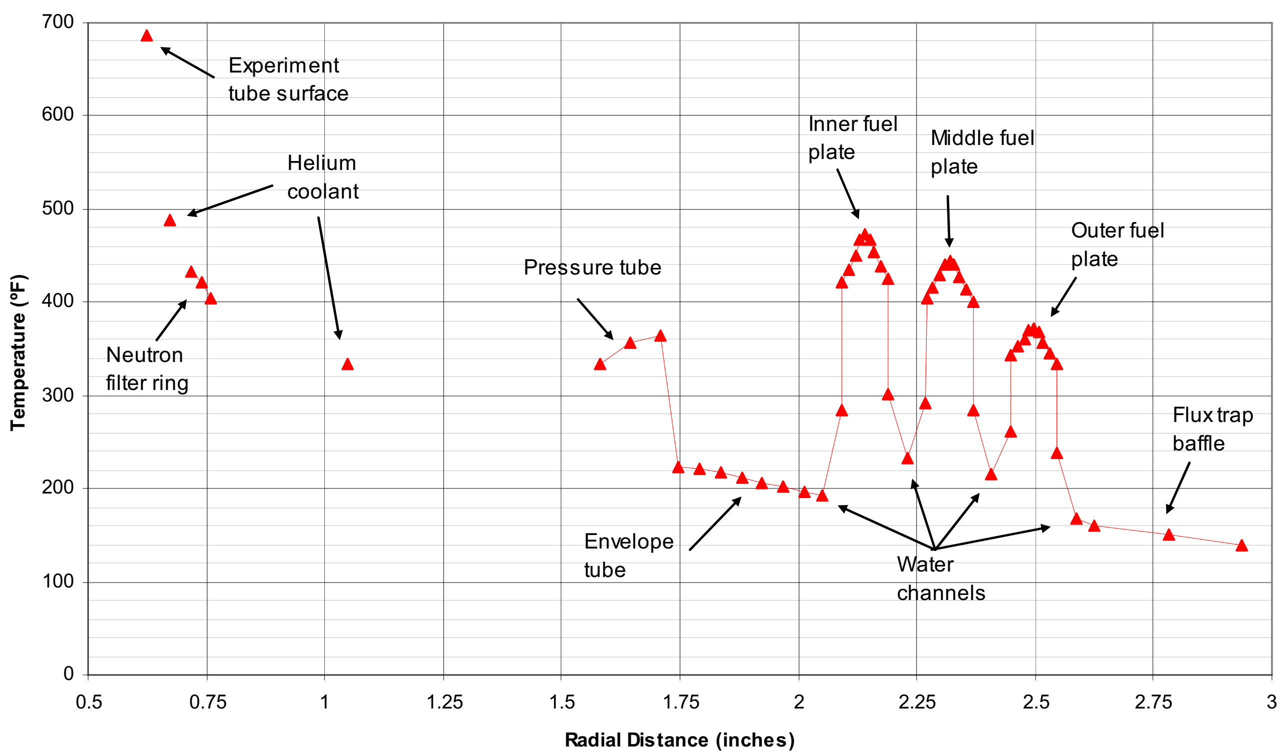

Fig 2. Maximum predicted operating temperatures.